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Evaluation of the chemical composition and functional properties of *gari* from Liberia

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ABSTRACT

The regular use of local cassava varieties and the exclusion of the fermentation step in the processing of gari in Liberia may affect the composition and properties of gari, hence the need to evaluate its chemical composition and functional properties. Gari samples were randomly collected from markets (35) and processing centers (24) in Rivercess, Grand Bassa, Bomi, Margibi, Sinoe, Gbarpolu, Montserrado, and Grand Capemount Counties, and packaged in airtight polythene bags prior to laboratory analyses using standard methods, and the data generated analysed using Statistical Package for Social Scientist (SPSS Version 21). The results showed that the chemical composition of the gari samples is moisture content 6.40%; cyanogenic potential 20.70 mg HC/kg; pH 5.38; starch content 62.05%; fat content 2.77%; ash content 1.20%; total titratable acidity (TTA) 0.01 g/100 mL; and protein content 1.05%. The functional properties of the gari samples is water absorption capacity 525.13%; oil absorption capacity 175.59%; least gelation concentration 6.13%; dispersibility 39.48%; bulk density 65%; swelling power (SWP) 8.04%; and solubility index 14.96%. Peak viscosity is 165.60 RVU; trough viscosity 149.10 RVU; breakdown viscosity 16.50 RVU; final viscosity 251.02 RVU; setback viscosity 101.92 RVU; peak time 6.48 min; and pasting temperature 50.82 °C. All the chemical composition and functional properties were significantly ($p < 0.05$) affected by the products except for ash, TTA, and protein contents as well as the SWP ($p > 0.05$). The addition of moringa leaf powder, groundnut paste, roasted coconut chips, and milk powder increased the fat and protein contents of the gari compared to the non-enriched products. *Gari* of improved quality can be produced in Liberia if the available local cassava varieties with high cyanide content are fermented before roasting or the newly introduced low cyanide varieties are used for *gari* production with the stipulated standard operating procedures.

Introduction

Besides serving as the primary staple food of millions of people in the tropics and subtropics, cassava is used as a raw material in the manufacturing of processed food, animal feeds, and industrial products. Wider utilization of products can be a catalyst for rural industrial development and raise the incomes of producers, processors, and traders. Cassava can also contribute to the food

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security status of its producing and consuming households (Saediman et al., 2016).

Together with rice, cassava is the second most important food crop in Liberia, but the consumption of the leaves makes it the first staple-protein food consumed in the country (MOA, 2010; Coulibaly, 2014). Cassava root has been processed into many fermented and unfermented products like gari, depah, starch, fufu powder, and tapioca. The quality of these products varies from one processor or county to another.

Gari is a granular food product produced by grating fresh roots into a mash, fermenting, de-watering, and dry roasting the dewatered cake into gelatinized particles (James et al., 2012). Gari is the most popular food from cassava that is eaten in Liberia and other West African countries (MOA, 2010).

Though acceptability depends on conformity with the major quality attributes demanded, the use of local cassava varieties with high cyanide contents and the current traditional methods of processing without fermentation in Liberia might affect the quality, vis-à-vis standard specifications. Some of the gari sold in Liberia markets is enriched with moringa leaf powder, groundnut paste, coconut chips, and milk powder, without proper knowledge of nutrient improvements in food products, thus contributing to the changes in chemical composition and functional properties. Therefore, the aim of this study was to evaluate the chemical composition and functional properties of *gari* from Liberia.

Materials and methods

Sample collection

Gari products traded in Liberia were collected from thirty-four markets and twenty-four processing centers of eight counties; Rivercess (two markets with none from processing centre), Grand Bassa (six markets and three processing centres), Bomi (two markets and one processing centre), Margibi (six markets and three processing centres), Sinoe (eight markets and two processing centres), Gbarpolu (two markets with none from processing centre), Montserrado (ten markets and seven processing centres), and Grand Capemount (four markets and two processing centres).However, not all types of gari were produced and marketed in all the different counties, thus, the reason for the analyses based on products and counties, and not markets and processing centres, were the collected samples. Different gari samples from each county were kept separately in polypropylene bags and transported to the laboratory for analyses. Each of the samples was representative of the sampling region, thus the unequal sampling sizes were reported. Table 1 shows the gari types and the processing methods.

Determination of chemical composition of gari products

Moisture content: Moisture content (MC) was determined using the method of AOAC (2000). A pre-weighed clean dry dish with about 3 g of sample was weighed and placed in a well-ventilated oven (draft air Fisher Scientific Isotemp® Oven model 655F, Springfield, USA) maintained at 103 ± 2 °C for 24 h. The loss in weight was recorded as MC.

pH value: Five gram samples of gari were suspended in deionized water for 5 min at a ratio of 1:5 (w/v) and pH was measured using a digital pH meter (Orion Research Inc., USA, Model 720A) (AOAC, 2000).

Titratable acidity (TTA): Titratable acidity of each sample was determined by titration of 25 mL of the decanted homogenate used for pH determination against 0.1 M NaOH. The relative amount of lactic acid was calculated as percentage lactic acid on a dry matter basis (AOAC, 2000).

$$\% \text{ lactic acid} = \frac{Titre\ value\ X\ Nomality\ of\ alkalis}{weight\ of\ sample} \times 100$$

Cyanogenic potential: The cyanogenic potential of the samples was determined using the procedure of Essers et al. (1993). The sample (30 g) was homogenized in 250 mL of 0.1 M orthophosphoric acid, the homogenate was centrifuged and the supernatant was extracted. Amount of 0.1 mL of the extract was treated with linamarin standard to get the total cyanogenic potential. Another assay was run with 0.1 mL of extract, but 0.1 mL of 0.1 M phosphate buffer (pH 6.0) was used to give the non-glucosidic cyanogenic potential. A third assay was run with 0.6 mL of extract that was added to 3.4 mL of McIlvaine buffer (pH 4.5). It was properly mixed, and 0.2 mL of 0.5 % chloramine T and 0.8 mL of colour reagent was added to give the free cyanogen. A standard curve was then obtained by plotting absorbance values (y-axis) against standard concentration (x-axis).

Linamarin = 125 mL/ (sample weight x 0.01093)

Non-glucosidic cyanogen = 125 mlL (sample weight × 0.03176)

Free cyanide = 125 mL/(sample weight × 0.04151).

Table 1. *Gari* types and processing methods in Liberia

Type of gari	Processing method
White gari	Peeling, washing, grating, bagging and dewatering, granulation, and roasting in earthenware pots.
Yellow gari	Same processing steps as above with mixing of palm oil to the granules before roasting
Coconut-fortified gari	Grating and roasting of matured coconut pulp before mixing with white gari
Groundnut-fortified gari	Roasting and milling of groundnuts before mixing with white gari
Groundnut-moringa-fortified gari	Drying of fresh moringa leaves, milling, and mixing with groundnut-fortified gari

Ash content: This was determined using the method of AOAC (2000) that involves burning off the moisture and all organic constituents at 600 °C for 5 h in a furnace (VULCANTM furnace model 3-1750). The weight of the residue after incineration was then recorded as the ash content.

$$\%\text{Ash content } = \left(\frac{w_3 - w_1}{w_2}\right) \times 100$$

W_3 = Wt. of crucible + ash
W_2 = Wt. the sample only
W_1 = Wt. of the crucible

Protein content: Crude protein content was determined by a Kjeldahl method using KjeltecTM model 2300 protein analyzer, as described in Foss Analytical Manual, AB (2003). About 0.2 g of sample was digested at 420 °C for 1 h to liberate the organically bound nitrogen in the form of ammonium sulphate. The ammonia in the digest (ammonium sulphate) was distilled into a boric acid receiver solution and titrated with a standard hydrochloric acid. A conversion factor of 6.25 was used to convert from total nitrogen to percentage crude protein (displayed on the screen of the protein analyzer).

Fat content: Fat content was determined using the method of AOAC (2000). Crude fat was extracted from 3 g of the sample with hexane using a fat extractor (Soxtec System HT-2 fat extractor), and the solvent was evaporated to get the fat. The difference between the initial and final weight of the extraction cup was recorded as the crude fat content.

$$\%\text{ fat } = \left(\frac{\text{Wt. of flask + fat} - \text{Wt. of the sample after drying}}{\text{Wt. of the sample before drying}}\right) \times 100$$

Determination of Functional properties

Bulk density: This was determined using the method of AOAC (2000). The sample (7 g) was placed into a 50-mL graduated measuring cylinder. The cylinder was then tapped gently against the palm of the hand until a constant volume was obtained, and the bulk density (BD) was calculated as follows:

$$\%\, BD = \frac{\text{Weight of sample}}{\text{Volume of sample after tapping}} \times 100$$

Water and oil absorption capacity: Water Absorption Capacity (WAC) and Oil Absorption Capacity (OAC) were determined using the method described by Beuchat (1977). Each 1 g sample was mixed with 10 mL of distilled water for WAC and with 10 mL of vegetable oil for OAC and blended for 30 s. Each was allowed to stand for 30 min and centrifuged at 3500 rpm for 30 min at room temperature. The supernatant (water/oil that was not absorbed by the flour samples) was decanted and the weight of water/oil absorbed by the flour was calculated and expressed as WAC/OAC.
Swelling power: This was determined in accordance with the method described by Leach et al. (1959), modified for small samples. A sample of 0.1 g was placed into a weighed test tube, weighed, and 10 mL of distilled water was added. The test tube was heated in a water bath at a temperature of 60 °C for 30 min with continuous shaking. After the heating, the test-tube was centrifuged at 2200 rpm for 15 min to facilitate the removal of the supernatant, this was carefully decanted and the weight of the starch paste was taken. The swelling power (SWP) was calculated as:

$$\%\, SWP = \frac{\text{Weight of starch paste}}{\text{Weight of dry starch sample}} \times 100$$

Solubility index: The Solubility Index (SI) was evaluated by placing l g of the sample into a test tube along with 20 mL of distilled water. The test tube was heated in a water bath at a temperature of 60 °C for 30 min. After the heating, the test tube was centrifuged at 2500 rpm for 20 min; 10 mL of the supernatant was decanted and dried to a constant weight, with the solubility expressed as a percentage by the weight of dissolved starch from the heated solution (Kainuma et al., 1967). The SI was calculated as:

$$\% \text{ SI} = \frac{\text{Weight of solubles}}{\text{Weight of sample}} \times 100$$

Least Gelation Concentration: The method developed by Coffman and Gracia (1977) was used in the determination of the Least Gelation Concentration (LGC). Appropriate sample suspensions were added to test tubes each containing 5 mL of distilled water, to make 2–20% (w/v) suspensions. The test tubes containing these suspensions were heated for 1 h in boiling water (bath) then cooled rapidly under running tap water and further cooled for an hour under running water. The LGC was determined when the sample from the inverted test tube did not fall or slip.

Dispersibility: This was determined using the method described by Kulkarni et al. (1991). The samples (10 g each) were added to a 100-mL measuring cylinder along with distilled water, to reach a volume of 100 mL. The mixture was stirred vigorously and allowed to settle for three hours. The volume of the settled particles was recorded and subtracted from 100. The difference was reported as dispersibility percentage.

Pasting properties of dried cassava products: The pasting characteristics of the samples were determined using a Rapid Visco Analyzer (RVA) (Model RVA-4C, Newport Scientific, Warriewood, Australia) interfaced with a personal computer equipped with the Thermocline Software supplied by the same manufacturer (Newport Scientific, 1998). Each sample (3 g) was weighed into a canister and made into slurry by adding 25 mL of distilled water. This canister (covered with a stirrer) was inserted into the RVA. The heating and cooling cycles were programmed as follows: the slurry was held at 50 °C for 1 min, heated to 95 °C within 3 min and held at 95 °C for 2 min. It was subsequently cooled to 50 °C within 3 min and held at 50 °C for 2 min while maintaining a rotation speed of 160 rpm. The viscosity was expressed as Rapid Viscosity Units (RVU). The parameters determined, automatically, by the instrument, were peak viscosity (the maximum viscosity during pasting), the breakdown viscosity (the difference between the peak viscosity and the minimum viscosity during pasting), the setback viscosity (the difference between the maximum viscosity during cooling and the minimum viscosity during pasting), the final viscosity (the viscosity at the end of the RVA run), the pasting temperature (°C) (the temperature at which there was a sharp increase in the sample suspension's viscosity after the commencement of heating) and the peak time (min) (the time taken for the paste to reach peak viscosity).

Results and Discussion

Chemical composition of gari

Table 2 shows the chemical composition of gari samples produced and sold in Liberia. The mean of the MC is 6.40%, cyanogenic potential (CNP) 20.70 mg HC/kg, pH 5.38, starch content 62.05%, fat content 2.77%, ash content 1.20%, TTA 0.01 g/100 mL, and protein content 1.05%. Additionally, all the chemical properties were significantly ($p < 0.05$) affected by the products except ash, TTA, and protein contents ($p > 0.05$). The counties of origin have a significant effect ($p < 0.05$) on all chemical properties except fat content ($p > 0.05$). The interaction between the products and the counties significantly affected the starch content and pH (Table 2).

The MC of the products ranged from 3.53 to 6.78%, with white gari having the highest value while groundnut-enriched gari had the lowest. Gari products from Grand Bassa (5.03%) have lower MC than those of Gbarpolu (7.25%) with higher MC (Table 2). Sanni et al. (2005) and Bankole et al. (2013) reported that low MC ensures the longer shelf life of food products. This implied that all the gari products would store well with longer shelf life, as the average MC is below the Codex and Standard Organization of Nigeria (SON) recommendation of 10% (Sanni et al., 2005; Codex, 1989). The lower MC of all the products might be attributed to the good effect of the roasting method (Ukpabi and Ndimele, 1990).

The CNP content of the products ranged from 10.90 to 26.80 mg HCN/kg. Yellow gari had the lowest content while groundnut-moringa-enriched gari had the highest value. Montserrado gari has higher CNP (25.00 mg HCN/kg) while those samples from Grand Bassa (14.10 mg HCN/kg) have lower value (Table 2). The European Food Safety Authority and SON stipulate that the standard for hydrogen cyanide in cassava products is 10 mg HCN/kg. The implication of this is that all the gari products from Liberia are higher in cyanide and might not be too safe for consumption, except the yellow gari with CNP content that is slightly higher than the recommended standard (Sanni et al., 2005; JECFA, 2009). In addition, the presence of cyanide above safe levels in foods may pose health risks among consumers, which may include Tropical Ataxic Neuropathy (TAN) (Akintomiwa and Onifade, 1994). The TAN has been reported to be associated with consumption of high-level of cyanide in cassava-based meals and common among older people (Bradbury, 2006). High CNP in the products may be attributed to the use of local varieties with high cyanide content by the processors in Liberia, and also to the fact that too little or no fermentation is allowed to take place during processing (Komolafe and Arawande, 2010). During this study it was observed that the processors, after harvesting and peeling the cassava root, grate, press, and roast the dewatered mash on the same day, using the traditional method without fermentation for gari production;. International Institute of Tropical Agriculture (IITA) is presently working in collaboration with the Ministry of Agriculture through the Smallholder Agricultural Productivity Enhancement and Commercialization (SAPEC) project, to train Liberian processors for the standard operating procedures for gari. There is also intention to substitute improved cassava varieties with low CNP with the local varieties to make gari of high quality available in the markets nationally.

The low TTA (0.01 to 0.02 g/100 mL) value in all gari products showed that little fermentation or none was done during processing (Oyewole, and Odunfa, 1990; Udoro et al., 2014) and was below the Codex and SON standard of 1 g/100 mL of cassava products (Sanni et al., 2005; Codex 1989). Groundnut-enriched gari had the highest pH value (6.59) while yellow gari had the lowest (5.17). Also, gari from Sinoe had a higher pH (5.66) while those from Grand Capemount had the lowest (5.08) (Table 2). The lower pH of gari from Grand Capemount might be attributed to some level of fermentation and the consumers' preference for the products in the area.

Baah et al. (2009) reported that ash content is a reflection of the mineral status, even though high ash content may indicate a high contamination of the product. The ash content of the products ranged from 0.44 to 1.59%, with groundnut–moringa-enriched gari having the highest value while groundnut–enriched-gari had the lowest. At the county level, Sinoe gari had the highest ash content (1.58%) while those from Margibi had the lowest value (0.92%) (Table 2). The high ash content in gari from Sinoe, and especially in the groundnut–moringa-enriched gari, might have resulted from contamination with foreign particles or heavy metals from the grating machine and during roasting (Otutu et al., 2013). However, all the products are within the Codex regulatory standards of 1.5% ash content, except for the groundnut–moringa-enriched gari that had higher values (Codex 1989). High ash content of the groundnut–moringa-enriched gari may be due to the addition of the moringa leaves, since gari that was mixed only with groundnut has the lowest ash content. However, differences in the cassava varieties used may affect the ash content of gari.

Table 2. Chemical properties of *gari* from Liberia.

Products	N	Moisture (%)	CNP (mg HCN/kg)	TTA (g/100 mL)	pH	Ash (%)	Starch (%)	Fat (%)	Protein (%)
Coconut-enriched *gari*	8	5.88 ± 0.88^{ab}	18.10 ± 0.49^{ac}	0.02 ± 0.01^{a}	5.72 ± 0.18^{b}	1.34 ± 0.18^{ab}	50.27 ± 9.64^{bc}	4.41 ± 1.80^{c}	1.26 ± 1.18^{a}
Groundnut-enriched *gari*	2	3.53 ± 0.18^{c}	14.40 ± 0.13^{bc}	0.01 ± 0.00^{a}	6.59 ± 0.01^{a}	0.44 ± 0.02^{c}	42.25 ± 0.74^{c}	19.96 ± 0.49^{b}	0.50 ± 0.00^{a}
Groundnut-*moringa*- enriched gari	2	4.95 ± 0.37^{ac}	26.80 ± 0.06^{a}	0.02 ± 0.00^{a}	5.70 ± 0.02^{b}	1.59 ± 0.01^{a}	59.69 ± 1.09^{ab}	30.46 ± 0.11^{a}	1.69 ± 0.08^{a}
Milk-enriched *gari*	2	4.34 ± 0.01^{bc}	16.60 ± 0.06^{ac}	0.01 ± 0.00^{a}	6.47 ± 0.01^{a}	0.90 ± 0.01^{bc}	60.33 ± 0.23^{ab}	1.94 ± 6.48^{c}	0.66 ± 0.04^{a}
White *gari*	90	6.78 ± 1.63^{a}	$22.30\pm0.83a^{b}$	0.01 ± 0.01^{a}	5.32 ± 0.27^{c}	1.23 ± 0.43^{ab}	62.60 ± 11.00^{ab}	0.75 ± 0.00^{c}	1.07 ± 1.85^{a}
Yellow *gari*	12	4.93 ± 0.96^{ac}	10.90 ± 0.46^{c}	0.01 ± 0.00^{a}	5.17 ± 0.19^{c}	1.04 ± 0.31^{ab}	69.77 ± 5.81^{a}	0.95 ± 0.29^{c}	0.77 ± 0.47^{a}
Counties									
Montserrado	34	7.17 ± 1.52^{a}	25.00 ± 0.65^{ab}	0.02 ± 0.01^{ab}	5.36 ± 0.30^{bc}	1.22 ± 0.42^{ac}	$56.16\pm6.27b^{c}$	6.07 ± 11.42^{a}	0.81 ± 0.72^{b}
Margibi	18	5.86 ± 2.55^{bc}	19.70 ± 0.60^{bc}	0.01 ± 0.00^{c}	5.61 ± 0.53^{a}	0.92 ± 0.49^{c}	64.15 ± 13.72^{ab}	4.72 ± 7.33^{a}	0.65 ± 0.11^{b}
Bomi	6	5.73 ± 1.63^{bc}	23.10 ± 0.75^{ab}	0.01 ± 0.00^{c}	5.11 ± 0.12^{de}	1.13 ± 0.41^{bc}	62.86 ± 11.48^{ac}	0.44 ± 0.09^{a}	6.269 ± 4.88^{a}
Gbarpolu	4	7.25 ± 0.29^{a}	22.80 ± 0.23^{ab}	0.01 ± 0.00^{bc}	5.43 ± 0.12^{b}	1.43 ± 0.12^{ab}	71.48 ± 4.78^{a}	0.27 ± 0.08^{a}	0.64 ± 0.13^{b}
Rivercess	4	5.58 ± 0.21^{bc}	18.70 ± 0.64^{bc}	0.02 ± 0.01^{a}	$5.27\pm0.18^{b-d}$	1.34 ± 0.31^{ab}	54.52 ± 4.76^{c}	1.83 ± 1.98^{a}	0.67 ± 0.09^{b}
Grand Capemount	12	6.83 ± 1.01^{ab}	28.10 ± 0.76^{a}	0.02 ± 0.01^{a}	5.08 ± 0.17^{e}	1.09 ± 0.22^{bc}	$57.14\pm6.70b^{c}$	0.32 ± 0.12^{a}	0.56 ± 0.07^{b}
Sinoe	20	6.74 ± 1.06^{ab}	14.80 ± 0.85^{c}	0.01 ± 0.00^{c}	5.66 ± 0.19^{a}	1.58 ± 0.17^{a}	64.98 ± 15.31^{ab}	0.16 ± 0.11^{a}	0.85 ± 0.43^{b}
Grand Bassa	18	5.03 ± 1.01^{c}	14.10 ± 0.71^{c}	0.01 ± 0.00^{c}	$5.18\pm0.24^{c-e}$	1.10 ± 0.39^{bc}	70.40 ± 6.09^{a}	0.70 ± 0.43^{a}	0.86 ± 0.53^{b}
Mean		6.40	20.70	0.01	5.38	1.21	62.05	2.77	1.05
P Products		***	*	NS	***	NS	***	***	NS
P Counties		*	***	**	***	*	**	NS	***
P Products x Counties		NS	NS	NS	**	NS	***	NS	NS

N-Number of samples, CNP-Cyanogenic potential, TTA-Total titratable acidity, *$p<0.05$, **$p<0.01$, ***$p<0.001$, NS-Not significant. Means with different letters on the same column are significantly different at $p\leq0.05$

The starch content of gari products ranged between 42.25 and 69.77%. Gari from Gbarpolu had the highest starch content (71.48%) while that of Rivercess had the lowest value (54.52%). However, the recommended starch content in gari by the SON is 75% (Sanni et al., 2005). Yellow gari had the highest starch content and groundnut-enriched gari the lowest (Table 2). On the contrary, the low starch content in the groundnut-enriched gari might be due to the addition of groundnut paste, as reported by other researchers who worked on the fortification of gari with fat/protein rich foods (Onasoga et al., 2014; Oluwamukomi, 2015; Alozie and Ekerette, 2017). Additionally, the variation in the starch content of the white gari and the SON standard might be because of the difference in location, processing methods, and varieties used. This is also justified by the significant effect of the interaction between the products and the counties on the starch content (Table 2).

Cassava and its derived products are known to be very low in fat and protein contents. Consequently, the enrichment of gari samples with foods rich in fat and protein have been shown to increase the fat and protein contents (Bankole et al., 2013; Onasoga et al., 2014; Oluwamukomi, 2015; Alozie and Ekerette, 2017).. Of all the counties, Montserrado is known to be more involved in gari value addition (fortification) than production. This is evident in the high fat (6.07%) and protein (6.27%) contents of the gari from this county. The fat contents of the products ranged from 0.75 to 30.46% and the protein contents from 0.50 to 1.69%. Groundnut–moringa-enriched gari had the highest values for these nutrients: white gari had the lowest fat content and Groundnut-enriched gari had the lowest protein content (Table 2).

Functional properties of gari from Liberia

The functional properties were significantly ($p < 0.05$) affected by the products except for the swelling power (SWP). The counties where the products were collected also significantly ($p < 0.05$) affected the functional properties except the least gelation concentration (LGC) and dispersibility ($p > 0.05$), which were not significantly affected. This may be attributed to the different processing methods. However, the interaction between the products and the counties has no significant ($p > 0.05$) effect on all the functional properties (Table 3). The mean of the WAC of the products was 525.13%, OAC 175.59%, LGC 6.13%, dispersibility 39.48%, bulk density (BD) 65%, swelling power (SWP) 8.04%, and solubility index (SI) 14.96% (Table 3). The functional properties describe how ingredients behave during preparation and cooking, and how they affect the finished food product in terms of its appearance, taste, and consistency. This is very important, knowing well that gari in Liberia is enriched with other foods rich in macronutrients (fat and protein), and eaten as snacks. This is different from how gari is consumed in other African countries such as Nigeria, Ghana, Togo, and the Benin Republic, where gari is prepared into paste with hot water (Eba in Nigeria) and taken with the preferred stew, or eaten when mixed with cold water with the addition of milk, sugar, and groundnut.

The ability to absorb water is a very important property for most starchy foods, with reference to their functionality in foods. Milk-enriched gari (555.84%) had the highest WAC and groundnut-enriched gari (331.48%) had the lowest. Gari from Bomi (604.80%) was higher in WAC and that from Rivercess (467.87%) was lower (Table 3). The high WAC in the milk-enriched gari compared to the groundnut-enriched gari may be attributed to the protein content (Kinsella, 1976), as a positive but not significant correlation ($p > 0.05$; $r = 0$ .65) exists between the WAC and the protein content of the products (Table 5).

The Groundnut-moringa-enriched gari with the highest protein content had lower WAC. This may be associated with the fact that the roasting process did not properly gelatinize the starch, thus making the starch structure more tightly bounded with each other (Awoyale et al., 2016). The OAC, on the other hand, is very important, as oil acts as a flavouring retainer and improves the mouthfeel of foods (Kinsella, 1976). This property is very important if the gari is to be cooked into a thick paste (eba) and consumed with preferred soup (prepared with the addition of either palm or vegetable oil). The OAC was higher in white gari (179.87%) and lower in groundnut-enriched gari (124.61%), and with products from Grand Capemount (198.89%) having the highest OAC and those from Montserrado (160.21%) the lowest. The OAC of the white gari may be due to its high affinity for oil compared with the groundnut-enriched gari. It is also important to add that a significant negative correlation ($p < 0.05$; $r = –0.98$) exists between the OAC and the pH value of the products (Table 5).

The higher the LGC, the higher the amount of starchy food needed to form a gel (Kinsella, 1979). This means that only a small quantity of white gari (5.75%) may be needed to form a gel in hot water, owing to its low LGC, and the gari may be economical, since less will be required to make food gels compared to groundnut–moringa-enriched gari (10.17%) with higher LGC (Table 3).

Table 3. Functional properties of *gari* from Liberia.

Products	N	Water absorption capacity (%)	Oil absorption capacity (%)	Least gelation concentration (%)	Bulk density (%)	Dispersibility (%)	Swelling power (%)	Solubility index (%)
Coconut-enriched *gari*	8	386.31±44.88^{b}	156.59±4.58^{a}	6.55±3.36^{b}	66.00±0.03^{bc}	53.63±4.07^{ab}	7.49±1.03^{ab}	26.86±4.37^{a}
Groundnut-enriched *gari*	2	331.48±7.83^{b}	124.61±0.82^{b}	10.05±0.01^{a}	93.00±0.00^{a}	59.00±0.00^{a}	6.99±0.19^{ab}	22.07±0.45^{ab}
Groundnut-*moringa*- enriched *gari*	2	370.29±8.57^{b}	126.14±0.14^{b}	10.17±0.01^{a}	72.00±0.03^{b}	59.00±1.41^{a}	7.47±0.64^{ab}	17.74±1.42^{ab}
Milk-enriched *gari*	2	555.84±6.91^{a}	165.73±0.74^{a}	10.01±0.01^{a}	57.00±0.01^{d}	46.00±0.00^{bc}	6.69±0.06^{b}	21.84±0.02^{ab}
White *gari*	90	548.67±90.73^{a}	179.87±22.96^{a}	5.75±1.71^{b}	64.00±0.06^{cd}	37.04±6.97^{c}	8.16±0.89^{a}	13.13±6.62^{b}
Yellow *gari*	12	494.09±56.30^{a}	174.53±15.93^{a}	6.74±2.47^{b}	68.00±0.05^{bc}	40.75±7.02^{c}	8.01±0.92^{ab}	17.96±9.36^{ab}
Counties								
Montserrado	34	565.29±132.41^{ab}	160.21±16.02^{d}	6.00±2.24^{a}	64.00±0.06^{b-d}	40.35±10.00^{ab}	7.90±1.02^{ab}	15.66±8.15^{a}
Margibi	18	502.78±114.84^{b-d}	171.07±41.03^{cd}	6.19±2.15^{a}	65.00±0.11^{a-c}	40.94±12.31^{a}	8.34±1.06^{a}	15.63±6.42^{a}
Bomi	6	604.80±27.36^{a}	189.27±7.26^{ab}	5.11±0.06^{a}	59.00±0.05^{d}	33.83±3.19^{b}	8.00±1.03^{ab}	8.31±1.01^{b}
Gbarpolu	4	573.57±15.29^{a}	179.95±2.47^{bc}	5.06±0.01^{a}	66.00±0.02^{a-c}	37.25±7.27^{ab}	8.15±0.52^{ab}	15.30±8.31^{a}
Rivercess	4	467.87±25.69^{d}	170.94±1.02^{cd}	5.11±0.05^{a}	68.00±0.03^{ab}	37.25±7.80^{ab}	7.98±0.58^{ab}	9.40±0.88^{b}
Grand Capemount	12	546.27±26.22^{a-c}	198.89±12.44^{a}	5.92±1.94^{a}	61.00±0.06^{cd}	35.17±6.82^{ab}	7.36±0.59^{b}	9.10±3.78^{b}
Sinoe	20	488.23±49.46^{cd}	186.59±12.07^{a-c}	6.60±2.37^{a}	70.00±0.04^{a}	40.40±5.91^{ab}	8.23±0.71^{ab}	15.69±6.70^{a}
GrandBassa	18	473.90±56.72^{d}	176.89±15.66^{bc}	6.74±2.44^{a}	66.00±0.05^{ab}	41.11±6.52^{a}	8.23±0.91^{ab}	19.45±9.22^{a}
Mean		525.13	175.59	6.13	65.00	39.48	8.04	14.96
P Products		***	**	***	***	***	NS	**
P Counties		***	***	NS	***	NS	*	***
P Products x Counties		NS	NS	NS	NS	NS	NS	NS

N-Number of samples, *$p<0.05$, **$p<0.01$, ***$p<0.001$, NS-Not significant. Means with different letters on the same column are significantly different at $p \leq 0.05$

The high LGC of the groundnut–moringa-enriched gari may be due to its high protein content. This is because Ogunwolu et al. (2009) reported that a higher concentration of protein is often required for gelation. Gari from Grand Bassa (6.74%) had higher LGC and the one from Gbarpolu (5.06%) had the lowest.

Furthermore, groundnut-enriched gari and groundnut–moringa-enriched gari (59.00%) may be easily reconstituted during food preparation, and might also mix easily with other food ingredients owing to their high dispersibility when compared to white gari (37.04%) (Awoyale et al., 2017). Gari products from Grand Bassa (41.11%) may be easily reconstituted in water without lump formation due to high dispersibility, while lump formation may be likely in gari from Bomi (33.83%) when soaked in water because of its low dispersibility (Kulkarni et al., 1991). The high dispersibility in the groundnut-enriched gari and groundnut–moringa-enriched gari may be attributed to their high pH values, as a significant positive correlation ($p < 0.05$; $r = 0.92$) exists between dispersibility and pH value (Table 5).

The SWP of starchy foods reflects the extent of associative forces within the granules, therefore, the higher the SWP, the lower the associative forces (Sanni et al., 2005). Ukpabi and Ndimele (1990), on the other hand, described good quality gari as the one which can swell up to at least 3 times its original volume. This implied that white gari (8.16%) with higher SWP has granules with lower associative forces when compared with those of milk-enriched gari (6.69%) with lower SWP (Table 3). The high-fat content of the milk-enriched gari may be responsible for its lower SWP. This is because a significant negative correlation ($p < 0.05$; $r = -0.88$) exists between SWP and fat content (Table 5). However, all gari products may be of good quality in terms of their SWP, since they all swell up to at least 3 times their original volume in water (Ukpabi and Ndimele, 1990). The SI of the products ranged from 13.13 to 26.86%; coconut-enriched gari has the highest and white gari the lowest. Gari from Grand Bassa (19.45%) was higher in SI and those from Bomi (8.31%) were lower (Table 3). The high SI observed in the coconut-enriched gari may be associated with its protein content and the interactive forces within the protein molecules (Adebowale et al., 2005; Pelegrine, and Gasparetto, 2005).

It has been established that the lower the BD value, the higher the amount of gari that could be packaged in each volume of the container, which will reduce the space occupied, packaging cost, and transportation cost (Komolafe and Arawande, 2010). This means that milk-enriched gari (57%) with the lowest BD will occupy less space within packaging material and thus, reduce transportation costs, while this may not be the case with groundnut–moringa-enriched gari (93%) due to its high BD (Table 3). Additionally, it may be easier and less costly in terms of transportation to convey gari from Bomi (59%) to other parts of Liberia due to its low BD when compared to conveying Sinoe gari (70%) to other parts of the country. However, the type of vehicle used and road network will also affect the transportation of the products from one place to another.

Pasting properties of gari

The pasting properties of gari are shown in Table 4. The results showed that the pasting properties were significantly affected ($p < 0.001$) by the products except for the breakdown viscosity and pasting temperature ($p > 0.05$). The county origin also affected the pasting properties significantly ($p < 0.001$) except for the peak time and pasting temperature. However, the interaction between the products and the counties has no significant effect ($p > 0.05$) on the pasting properties. The mean of the pasting properties of the products are as follows; peak viscosity 165.60 RVU, trough viscosity 149.10 RVU, breakdown viscosity 16.50 RVU, final viscosity 251.02 RVU, setback viscosity 101.92 RVU, peak time 6.48 min., and pasting temperature 50.82 °C (Table 4). The pasting properties of the varieties of gari are important in predicting their behaviour during and after cooking. This is because the product is sometimes consumed in the form of a cooked thick paste (eba) or steamed product (acheke).

White gari (183 RUV) had the highest peak viscosity and groundnut-enriched gari (21.88 RVU) had the lowest. Gari from Bomi (283.08 RVU) is high in peak viscosity and that of Rivercess (104.10 RVU) is lower (Table 4). This implies that Bomi gari has a weak granular structure in its starch when compared to those from Rivercess with a low peak viscosity (Awoyale et al., 2017). The low peak viscosity in the groundnut-enriched gari might be attributed to the addition of groundnut paste, which may have interfered with its swelling ability. This is because peak viscosity is also an indication of the extent of starch swelling before its physical breakdown (Akinwale et al., 2017).

The trough viscosity measures the ability of the starch paste to withstand breakdown during cooling (Adegunwa et al., 2017). White gari (163.84 RVU) had the highest trough viscosity and groundnut-enriched gari (13.79 RVU) had the lowest. Similarly, gari from Bomi (268.80 RVU) is higher in trough viscosity and that of Rivercess (97.58 RVU) is lower (Table 4). The viscosity that determines the stability of starch paste after cooking is the breakdown viscosity. The higher the breakdown viscosity, the lower the stability of the starch paste after cooking (Akinwale et al., 2017). This implies that eba produced from White gari (19.20 RVU) with the highest breakdown viscosity may not be as stable after cooking as that of Coconut-enriched gari (4.47 RVU). Similar behaviour may be observed in eba produced from gari from Gbarpolu (38.44 RVU) and Rivercess (6.52 RVU) (Table 4).

The final viscosity indicates the resistance of the viscous paste (eba) to shear stress during stirring and its stability after cooking and cooling (Ogunwolu et al., 2009). The final viscosity of the products ranged from 35.38 to 305.78 RVU, with yellow gari having the highest and the groundnut-enriched gari the lowest (Table 4). This depicts that eba from yellow gari produced in Bomi (356.11 RVU) might be more stable after cooling than that of Rivercess (192.30 RVU) (Table 4). This is due to the high final viscosity of the Bomi gari. In addition, the high final viscosity of the yellow gari may be due to its high starch content. This is because a significant positive correlation ($p < 0.05$; $r = 0.84$) exists between the final viscosity and the starch content (Table 5).

The viscosity that determines the level of retrogradation or reordering of starch molecules after cooling is the setback. Setback viscosity also affects the digestibility of starchy foods; the higher the setback viscosity the lower the digestibility (Shittu et al., 2001; Alamu et al., 2017). Consequently, groundnut-enriched gari (21.58 RVU) with the lowest setback viscosity may be digested more easily and quickly than yellow gari (142.18 RVU) with the highest setback viscosity. Eba produced from yellow gari may retrograde faster compared to that of groundnut-enriched gari. Gari produced from Grand Bassa (141.08 RVU) had higher setback viscosity and that of Montserrado (82.71 RVU) was lower (Table 4). A significant positive correlation ($p < 0.05$; $r = 0.91$) was observed between the setback viscosity and the starch content of the products (Table 5).

The addition of fortificants (groundnut paste, moringa leaf powder, coconut chips, and milk powder) to the gari generally reduced the values of all the pasting properties. This is similar to the observations of other researchers who worked on food fortification (Awoyale et al., 2016, Bamigbola et al., 2016; Akinwale et al, 2017; Adegunwa et al., 2017; Alozie and Ekerette, 2017). However, all the products may be cooked into eba at a temperature of < 60 °C and time of ≤ 7 min., which implied low energy cost (Fasasi et al., 2007).

Table 4. Pasting properties of *gari* from Liberia.

Products	N	Peak viscosity (RVU)	Trough viscosity (RVU)	Breakdown viscosity (RVU)	Final viscosity (RVU)	Setback viscosity (RVU)	Peak Time (min.)	Pasting Temp (ºC)
Coconut-enriched *gari*	8	47.48±21.26[b]	43.01±19.61[b]	4.47±2.13[a]	93.00±35.83[bc]	49.99±17.40[cd]	6.93±4.14[a]	49.99±0.93[a]
Groundnut-enriched *gari*	2	21.88±1.94[b]	13.79±5.36[b]	8.09±7.30[a]	35.38±17.74[c]	21.58±12.37[d]	4.00±4.14[b]	48.93±2.16[a]
Groundnut-*moringa*-enriched *gari*	2	29.25±2.72[b]	22.63±3.83[b]	6.63±1.12[a]	77.42±4.48[c]	54.79±0.65[cd]	6.97±0.05[a]	48.85±2.12[a]
Milk-enriched *gari*	2	90.25±12.26[b]	84.79±12.32[b]	5.46±0.06[a]	159.25±13.79[b]	74.46±1.47[bc]	7.00±0.00[a]	49.03±2.02[a]
White *gari*	90	183.04±76.57[a]	163.84±67.59[a]	19.20±20.71[a]	268.46±72.78[a]	104.61±26.23[b]	6.45±0.57[a]	51.22±8.07[a]
Yellow gari	12	172.80±30.12[a]	163.60±28.56[a]	9.19±4.39[a]	305.78±42.89[a]	142.18±31.82[a]	6.59±0.40[a]	49.29±1.37[a]
Counties								
Montserrado	34	158.03±80.47[c-e]	139.21±65.24[c-e]	18.82±21.81[b]	221.93±72.00[c]	82.71±20.52[b]	6.36±0.64[a]	49.52±1.14[b]
Margibi	18	143.56±110.13[de]	124.58±96.09[de]	18.99±23.76[b]	208.42±134.08[c]	83.84±40.82[b]	6.26±1.37[a]	49.63±1.06[b]
Bomi	6	283.08±79.78[a]	268.80±73.92[a]	14.28±6.15[b]	356.11±62.17[a]	87.31±17.07[b]	6.59±0.21[a]	48.99±1.21[b]
Gbarpolu	4	221.73±17.88[b]	183.29±24.24[bc]	38.44±35.84[a]	278.69±26.08[b]	95.40±10.96[b]	6.20±0.70[a]	49.59±1.33[b]
Rivercess	4	104.10±22.93[e]	97.58±24.67[e]	6.52±2.83[b]	192.30±36.09[c]	94.71±13.23[b]	6.80±0.24[a]	49.86±0.61[b]
Grand Capemount	12	206.61±68.21[bc]	192.16±68.83[b]	14.45±5.11[b]	320.96±82.96[ab]	128.80±23.39[a]	6.67±0.37[a]	57.33±17.16[a]
Sinoe	20	119.33±35.95[e]	111.17±31.08[e]	8.16±7.16[b]	217.79±45.82[c]	106.62±18.66[b]	6.73±0.38[a]	52.51±9.86[a]
GrandBassa	18	188.06±49.27[b-d]	169.70±45.13[b-d]	18.36±19.93[b]	310.78±40.06[ab]	141.08±35.30[a]	6.45±0.68[a]	49.31±1.34[b]
Mean		165.60	149.10	16.50	251.02	101.92	6.48	50.82
P Products		***	***	NS	***	***	***	NS
P Counties		***	***	**	***	***	NS	NS
P Products x Counties		NS	NS	NS	NS	NS	NS	NS

N-Number of samples, **p<0.01, ***p<0.001, NS-Not significant. Means with different letters on the same column are significantly different at p≤0.05.

Table 5. Pearson correlation of the functional and chemical properties of *gari* from Liberia.

	Cyanogenic potential	Moisture	pH	Sugar	Starch	Fat	Ash	Total titratable acidity	Protein
Water absorption capacity	0.57	0.61	-0.80	-0.38	0.70	0.15	0.73	0.19	0.65
Oil absorption capacity	0.31	0.79	-0.98**	-0.21	0.65	-0.12	0.70	0.21	0.57
Least gelation concentration	0.11	-0.83*	0.80	0.01	-0.37	0.60	-0.33	0.03	-0.13
Bulk density	-0.61	-0.69	0.70	-0.10	-0.67	0.04	-0.96**	-0.54	-0.82*
Dispersibility	-0.26	-0.71	0.92**	0.47	-0.71	0.14	-0.54	0.05	-0.40
Swelling power	-0.37	0.60	-0.59	-0.40	0.57	-0.88*	-0.00	-0.52	-0.30
Solubility index	-0.02	-0.29	0.29	0.85*	-0.63	0.39	0.09	0.73	0.27
Peak viscosity	0.07	0.64	-0.90*	-0.59	0.76	-0.29	0.38	-0.24	0.20
Trough viscosity	0.06	0.63	-0.91*	-0.58	0.78	-0.28	0.40	-0.21	0.22
Breakdown viscosity	0.12	0.57	-0.42	-0.59	0.33	-0.35	-0.04	-0.56	-0.14
Final viscosity	-0.00	0.58	-0.91*	-0.60	0.84*	-0.33	0.40	-0.22	0.19
Setback viscosity	-0.11	0.48	-0.87*	-0.60	0.91*	-0.39	0.38	-0.22	0.14
Peak time	0.37	0.56	-0.52	0.16	0.68	-0.31	0.81*	0.43	0.59
Pasting temperature	0.30	0.91*	-0.59	-0.00	0.19	-0.41	0.35	-0.04	0.24

*p<0.05, **p<0.01

Conclusion

This study showed that the chemical compositions (except for ash, TTA, and protein content) of the gari produced from Liberian counties differ significantly. The practice of adding moringa leaf powder, groundnut paste, roasted coconut chips, and milk powder caused the increase of fat and protein contents of the gari compared to the unenriched white gari. All the other chemical constituents meet Codex standards except for the CNP content, which is very high. Yellow gari might be safe for consumption since it is just 0.9 mg HCN/kg higher than the standard of 10 mg HCN/kg. Therefore, gari of high quality can be produced in Liberia if the available varieties with high cyanide content are fermented before roasting or the newly introduced low cyanide varieties are used for gari production with strict adherence to standard operating procedures.

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References

Adebowale, A. A., Sanni, L. O. and Awonorin, S. O. (2005): Effect of Texture Modifiers on the Physicochemical and Sensory Properties of Dried Fufu. *Food Sci. Technol. Int*. 11(5), 373–382.

Adegunwa, M. O., Adelekan, E. O., Adebowale, A. A., Bakare, H. A. and Alamu, E. O. (2017): Evaluation of nutritional and functional properties of plantain (Musa paradisiacal L.) and tiger nut (Cyperus esculentus L.) flour blends for food formulations. *Cogent Chem*. 3, 1383707. https://doi.org/10.1080/23312009.2017.1383707.

Akintomiwa, T. O. and Onifade, A. A. (1994): Fatal and non-fatal acute poisoning attributed to the cassava-based meal. *Acta Hortic.* 375, 285–288.

Akinwale, T. E., Niniola, D. M., Abass, A. B., Shittu, T. A., Adebowale, A. A., Awoyale, W., Awonorin, S. O., Adewuyi, S. and Eromosele, C. O. (2017): Screening of some cassava starches for their potential applications in custard and salad cream productions. *Food Measure* 11(1), 299–309.

Alamu, E. O., Maziya-Dixon, B. and Dixon, A. G. (2017): Evaluation of proximate composition and pasting properties of High Quality Cassava flour (HQCF) from cassava genotypes (Manihot esculenta Crantz) of β-carotene-enriched roots. *LWT-Food Science and Technology* 86, 501–506. https://doi.org/10.1016/j.lwt.2017.08.040

Alozie, Y. E. and Ekerette, Y. E. (2017): Proximate compositions, physicochemical and sensory properties of gari enriched with soybean, melon seed, and moringa seed flours. *Int. J. Nutr. Food Sci*. 6(2), 105–110.

AOAC (2000): Association of Official Analytical Chemists. Official Methods of Analysis, 17th Edition, Washington DC.

Awoyale, W., Abass, A. B., Ndavi, M., Maziya-Dixon, B. and Sulyok, M. (2017): Assessment of the potential industrial applications of commercial dried cassava products in Nigeria. *Food Measure.* 11 (2), 598–609. https://doi.org/10.1007/s11694-016-9428-7

Awoyale, W., Maziya-Dixon, B., Sanni, L. O. and Shittu, T. A. (2016): Effect of water yam (Dioscorea alata) flour enriched with distiller's spent grain on nutritional, chemical and functional properties. *Food Sci Nutr*. 4 (1), 1–134. https://dx.doi.org/10.1002%2Ffsn3.254

Baah, F. D., Maziya-Dixon, B., Asiedu, R., Oduro, I. and Ellis, W. O. (2009): The nutritional and biochemical composition of D. alata (Dioscorea spp.) tubers. *J. Food Agric. Environ.* 7(2), 373–378.

Bamigbola, Y. A., Awolu, O. O. and Oluwalana, I. B. (2016): The effect of plantain and tiger nut flours substitution on the antioxidant, physicochemical and pasting properties of wheat-based composite flours. *Cogent Food* Agric. *2016*, 2(1), 1245060. doi:10.1080/23311932.2016.1245060.

Bankole, Y. O., Tanimola, O. A., Odunukan, R. O. and Samuel, D. O. (2013): An Assessment of the Functional Properties, Proximate Composition, Sensory Evaluation and Rheological Value of Gari Enriched with Bambara Groundnut Flour (Voandzeia Subterranean Thouars). *Academic Journal of Interdisciplinary Studies* 2 (10), 165-173.

Beuchat, L. R. (1977): Functional and electrophoretic characteristics of succinylated peanut flour proteins. J. *Agric. Food Chem*. 25: 258–060.

Bradbury, J. H. (2006): Short communication—simple wetting method to reduce cyanogens content of Cassava flour. *J. Food Compos. Anal*. 19, 388–393.

Codex (1989): Codex Stan 151, Rev. 1-1995. Codex Alimentarius Commission Standard for gari. pp. 1-6.

Coffman, C. W., and Gracia, V. V. (1977): Functional properties of the amino acid content of a protein isolate from mung bean flour. *J. Food Technol*. 12, 473–484. https://doi.org/10.1111/j.1365-2621.1977.tb00132.x

Coulibaly, O., Arinloye, A. D., Faye, M. and Abdoulaye, T. (2014): Regional cassava value chains analysis in West Africa. Technical report.

Essers, A. J. A., Bosveld, M., Van der Grift, R. M. and Voragen, A. G. J. (1993): Studies on the quantification of specific cyanogens in cassava products and the introduction of a new chromogen. *J. Sci. Food Agric*. 63, 287–296. https://doi.org/10.1002/jsfa.2740630305

Fasasi, O. S., Adeyemi, I. A. and Fagbenro, O. A. (2007): Functional and pasting characteristics of fermented maize and Nile Tilapia (Oreochromis niloticus) flour diet. *Pakistan Journal of Nutrition*. 6, 304–309. http://dx.doi.org/10.3923/pjn.2007.304.309

Foss Analytical AB (2003): Manual for Kjeltec System 2300 Distilling and Titration Unit. Kjeldahl method of protein determination.

James, B., Okechukwu, R., Abass, A., Fannah, S., Maziya-Dixon, B., Sanni, L. O. and Lukombo, S. (2012): Producing gari from cassava: an illustrated guide for smallholder cassava processors. International Institute of Tropical Agriculture (IITA) Ibadan. Nigeria.

JECFA (2009): Joint FAO/WHO Food Standards Programme Codex Committee on Contaminants in Foods) 2009. Discussion Paper on Cyanogenic Glycosides; Prepared by the Electronic Working Group members (Australia, New Zealand, Netherlands, Brazil, European Community, Indonesia, Denmark, Ghana, Thailand, Tonga, Vanuatu, FAO, WHO and Nigeria). Third Session, Rotterdam, the Netherlands, 23–27 March.

Kainuma, K., Odat, T. and Cuzuki, S. (1967): Study of starch phosphates monoesters. *J. Technol, Soc. Starch* 14, 24 – 28.

Kinsella, J. E. (1979): Functional properties of protein foods. *Crit Rev Food Sci Nutr*. 1, 219–236.

Komolafe, E A. and Arawande, J. O. (2010): Evaluation of the quantity and quality of gari produced from three cultivars of cassava. *Journal of Research in National Development* 20, 2027–2039.

Kulkarni, K. O., Kulkarni, D. N. and Ingle, U. M. (1991): Sorghum malt based weaning food formulation preparation, functional properties and nutritive value. *Food Nutr. Bull*. 13(14), 322-327.

Leach, H. W., McGovern, D. L. and Schoch, T. J. (1959): Swelling and solubility patterns of various starches, the structure of granules. *Cereal Chem*. 36, 534–544.

Newport Scientific (1998): Applications Manual for the Rapid Visco Analyzer Using Thermocline for Windows. Newport Scientific Pty Ltd.: Warriewood, pp. 26.

Ogunwolu, S. O., Henshaw, F. O., Mock, H., Santos, A. and Awonorin, S. O. (2009): Functional properties of protein concentrate and isolates produced from cashew (Anacardium occidentale L.) nut. *Food Chem.* 115, 852–858. https://doi.org/10.1016/j.foodchem.2009.01.011

Oluwamukomi, M. O. (2015): Chemical and sensory properties of gari enriched with sesame seed flour (Sesamum indicum L.) *FUTA Journal of Research in Sciences* 1, 123–131.

Onasoga, M. O., Ayodele, D. O. and Oyeyipo, O. O. (2014): Chemical changes during the fortification of cassava meal (gari) with African breadfruit (Treculia africana) Residue. *Journal of Applied Science and Environmental Management* 18(3), 506–512.

Otutu, O. L., Ikuomola, D. S. and Udom, Q. (2013): Comparative evaluation of the quality of gari samples from six processing centers in Oriade LGA of Osun state, Nigeria. *Int. J. Res. Agric. Food Sci*. 4(19), 571-580.

Oyewole, O. B and Odunfa, S. O. (1990): Characterization and distribution of lactic acid bacteria in cassava fermentation during fufu production. *J. Appl. Biotechn.* 68, 145–152. https://doi.org/10.1111/j.1365-2672.1990.tb02559.x

Pelegrine, D. H. G. and Gasparetto, C. A. (2005): Whey proteins solubility as a function of temperature and pH. *LWT- Food Science and Technology* 38(1), 77–80. https://doi.org/10.1016/j.lwt.2004.03.013

Saediman, H., Aswar, M., Rosmawaty, L., Arimbawa, P. and Indarsyih, Y. (2016): Cassava Consumption and Food Security Status among Cassava Growing Households in Southeast Sulawesi. *Pakistan Journal of Nutrition* 15, 1008-1016.

Sanni, L. O., Maziya-Dixon, B. Akanya, J., Okoro, C. I., Alaya, Y., Egwuonwu, C. V., Okechukwu, R., Ezedinma, C., Akoroda, M., Lemchi, J., Okoro, E. and Dixon, A. (2005): Standards for Cassava Products and Guidelines for Export. IITA, Ibadan, pp. 69.

Shittu, T. A., Lasekan, O. O., Sanni, L. O. and Oladosu, M. O. (2001): The effect of drying methods on the functional and sensory characteristics of Pukuru-A fermented cassava product. *ASSET-An International Journal* 1, 9–16.

Udoro, E. O., Kehinde, A. T., Olasunkanmi, S. G. and Charles, T. A. (2014): Studies on the physicochemical, functional and sensory properties of gari processed from dried cassava chips. *J Food Process Technol*. 5, 293.

Ukpabi, U. J. and Ndimele, C. (1990): Evaluation of the quality of gari produced in Imo state. *NIFOJ* 8, 105–110.